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The climatology of field haydrying in northwest Europe

by N Thompson

SUMMARY

An objective assessment of the influence of weather on haymaking is made using a micrometeorological model of swath drying along with weather data from sites in northwest Europe. The model assumes an idealized swath with fixed initial moisture content, but treats explicitly the effects of temperature, humidity, radiation, wind speed, rain, dew, soil moisture and stubble transpiration on swath drying. The results represent the potential for field drying, over an assumed cutting season from May to September, and allow the construction of hay drying climatologies for different sites and therefore inter-site as well as inter-year comparisons. Features of the results include the large inter-annual variability in haydrying prospects, even at places with good climatologies for haydrying on average, and a marked association of rainfall and rate of swath drying. Information is also provided on aspects of the influence of swath conditioning on field drying. A brief discussion is given on some likely effects of the continuing increase of atmospheric CO₂ on haymaking.

1. INTRODUCTION

A previous Memorandum (Thompson, 1981) described the development of a bulk model of a drying swath which included explicitly the effects of temperature, humidity, wind speed and radiation on rate of drying, and also incorporated methods of estimating delays in drying caused by rain or dew on the swath: the influence of water vapour diffusing from the soil and stubble beneath the swath was also included. A further

Memorandum (Thompson, 1983) described briefly how the model was used with climatological data to compare the haymaking potential in a single year of two sites, in eastern England and west Wales. An analysis has now been carried out using meteorological data from a number of sites located in northwest Europe in order to obtain a broad climatology of the potential for field haydrying in this region.

2. RUNNING THE MODEL

The model was designed to be used with climatological data sets (daily values of maximum and minimum temperature, vapour pressure, windspeed, sunshine duration, rainfall and rainfall duration): an outline of its operation is given in Figure 1. A cut of hay was assumed possible on any day (at 0900) of a 140-day cutting season beginning 1 May. Each cut was followed until its moisture content fell to 25% (dry weight basis), or until 10 days had elapsed. The calculations were made for three periods each day (sunrise-0900, 0900-sunset, sunset-sunrise). The rate of formation of dew was calculated explicitly. Some calculations were also made with swath resistance to drying halved in order to simulate the drying of conditioned swaths. In all cases a moisture content of 400% was assumed when the grass was cut.

3. METEOROLOGICAL DATA

Meteorological observations from 32 stations in 5 countries were used in the analysis (Figure 2, Table 1): the data period was 1961 to 1980. Rainfall durations were not available for the German and Swiss stations, and were estimated using a duration/rainfall amount relationship obtained from data for Nancy in eastern France.

4. RESULTS AND DISCUSSION

The best hay is rarely made in longer than about 5 days, and the maximum moisture content for safe long-term storage is around 25%. Simple representations of the haydrying potential at the various sites are therefore the annual average number of cuts reaching this moisture content within 5 days, and also an indication of how large are departures in individual years from this average (Table 2). As expected, the warmer, drier sites provide the most favourable conditions for haydrying. However, even sites with generally acceptable climates for haydrying show great variations in individual years in the number of cuts drying quickly. In eastern England for example (Stansted and Finningley), the number, judged by the second worst or best in the 20-year sample, ranges from less than 20 to around 70, and in somewhat more favourable climates (eg Trier) the range can be even larger.

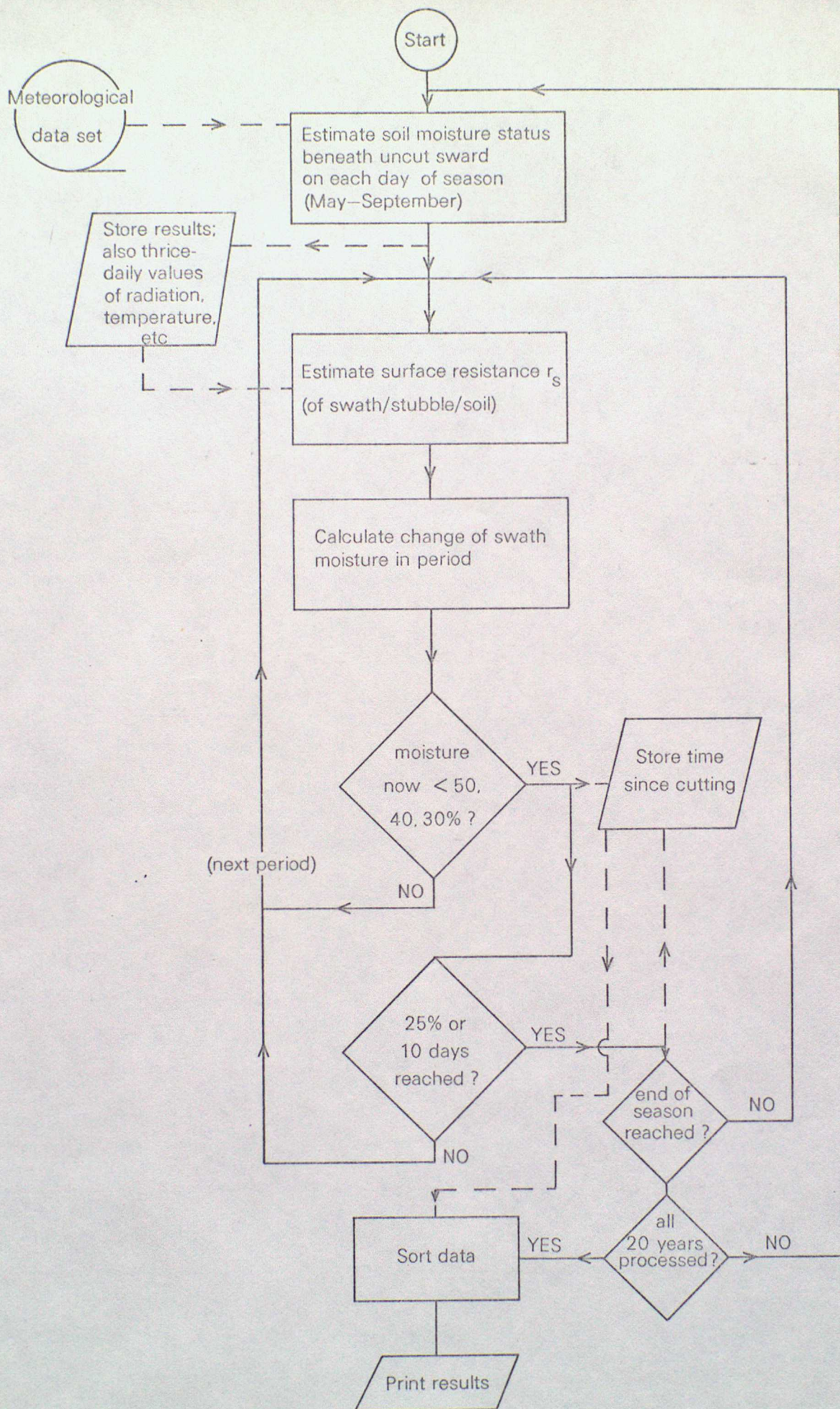


Figure 1 Outline of hay drying model



Figure 2 Meteorological stations providing data for the hay-drying analysis

TABLE 1 Stations used in the analysis

Country	Station name	Altitude (m)	May-September means (1961-1980)			
			Rainfall (mm)	Temperature (°C)	Vapour pressure (mb)	Sunshine (hours)
UK	Stornoway	3	383	11.3	11.9	728
	Dyce	65	326	11.9	11.4	749
	Eskdalemuir	242	548	11.3	11.4	693
	Carlisle	26	367	13.2	12.3	817
	Aldergrove	68	353	12.9	12.3	745
	Finningley	10	262	14.3	12.7	818
	Shawbury	72	293	13.6	12.6	806
	Aberporth	133	302	13.2	12.8	893
	Stansted	101	251	14.3	12.9	874
	Boscombe	126	272	14.1	12.9	943
	Mountbatten	27	328	14.3	13.7	1004
Holland	De Bilt	2	305	14.8	13.2	914
	Eelde	4	350	14.1	13.5	905
France	Lille	48	294	15.1	13.7	957
	Caen	78	268	14.9	13.7	1025
	Nancy	225	332	15.7	13.7	1015
	Rostrenen	262	297	14.2	13.2	900
	Orleans	126	254	16.1	13.5	1080
	Cognac	30	278	17.7	14.7	1151
	Clermont- Ferrand	332	340	16.7	13.0	1108
Germany	Bremen	4	333	15.3	13.1	933
	Hannover	53	311	15.0	13.1	938
	Trier	265	347	15.7	12.7	956
	Mannheim	96	339	17.1	13.4	1040
	Nurnberg	310	320	15.7	12.6	1057
	Munchen	527	542	15.1	12.6	1031
Switzerland	Zurich	556	582	15.9	12.8	979
	St Gallen	670	681	14.8	12.6	875
	Bern	570	511	15.7	13.1	1011
	Chur	582	450	16.2	12.1	949
	Geneva	416	412	16.6	13.2	1136
	Bever	1710	457	9.0	8.4	923

Table 2 Haydrying potential of various sites, expressed in terms of annual number of cuts drying to 25% moisture within 5 days.

Site	Average number of cuts (1961-1980)	Number of cuts in 2nd worst year	Number of cuts in 2nd best year
Stornoway	1	0 (17 years)	4 (1978)
Dyce	13	0 (1963,65,66,68)	29 (1975)
Eskdalemuir	7	0 (5 years)	21 (1977,1978)
Carlisle	17	3 (1961,79)	40 (1977)
Aldergrove	11	0 (1961,65,79)	33 (1977)
Finningley	41	18 (1966)	67 (1970,75)
Shawbury	25	7 (1966)	53 (1975)
Aberporth	16	5 (1966,67)	41 (1975)
Stansted	35	7 (1965)	76 (1975)
Boscombe	40	19 (1963,68)	74 (1975)
Mountbatten	27	5 (1965)	57 (1975)
De Bilt	36	10 (1972)	67 (1971)
Eelde	30	7 (1965)	58 (1971)
Lille	45	23 (1968)	69 (1970)
Caen	51	25 (1963)	80 (1961)
Nancy	50	17 (1972)	100 (1964)
Rostrenen	36	11 (1963)	53 (1975)
Orleans	77	46 (1968)	108 (1964)
Cognac	85	57 (1965)	109 (1962)
Clermont-Ferrand	76	51 (1971)	108 (1961)
Bremen	37	17 (1979)	77 (1976)
Hannover	37	12 (1965)	70 (1964)
Trier	48	20 (1972)	97 (1964)
Mannheim	57	26 (1968)	98 (1976)
Nurnberg	51	21 (1968)	86 (1976)
Munchen	27	12 (1974)	45 (1964)
Zurich	28	8 (1972)	57 (1964)
St Gallen	8	1 (1965,70,79)	21 (1964)
Bern	26	7 (1972)	55 (1976)
Chur	44	16 (1965)	73 (1962)
Geneva	59	31 (1965)	94 (1976)
Bever	1	0 (7 years)	22 (1976)

Seasonal changes in the values of the meteorological variables differ significantly at the various sites, with consequent variation in the times at which successful haydrying is most likely to be carried out. Thus (Figure 3), Stornoway - a cool maritime site, and Stansted - a site with both continental and (weak) maritime influences, differ from the continental sites of Nancy and St Gallen in having highest sunshine and radiation in the earlier part of the postulated seasons, and this leads to a different seasonal pattern of potential haymaking success (Figure 4(i)). Unfortunately the early advantage which Stornoway gains, particularly for cuts drying within 10 days to 40% (around the highest moisture content at which baling prior to further field curing or barn drying would take place), cannot often be realised because of the high water content of the leafy grass early in the season and the difficulty of drying therefore.

The plots in the second part of Figure 4 show inter-annual variability in haydrying prospects and demonstrate strikingly how few the opportunities can be in some years for making good hay, even for a site like Nancy where on average around one third of the cuts might be expected to dry to a low moisture content within five days. Such year-to-year variability has stimulated the development of mower-conditioners which accelerate drying by reducing swath resistance: results from simulations of such conditioned swaths appear in Figures 5 and 6. Clearly advantages accrue from conditioning, although the benefits are small at sites like Stornoway and Eskdalemuir which offer only poor prospects for drying.

The apparent advantages of conditioning are reduced somewhat when the amount of rain falling on the drying swath is considered. Table 3 shows that unconditioned swaths drying quickly to the point where they can be safely stored usually receive less than 1 mm of rainfall while wilting. Similar results are found for quickly-drying conditioned swaths for the United Kingdom, but conditioning allows substantially more slower-drying swaths to be harvested, on which larger amounts of rain have fallen. Thus, average rainfall on swaths reaching 25 to 40% moisture content at the end of 10 days wilting increased from 4 mm (unconditioned) to 9 mm (conditioned) at Stornoway, and from 7 to 13 mm at Eskdalemuir: therefore an increased number of cuts would suffer quality loss through leaching, following conditioning.

5. EFFECTS OF CLIMATE CHANGE

The consensus view at present is that the present interglacial climate will give way within the next 10000 years or so to the colder conditions of the next glaciation. Shorter-term fluctuations will occur in the meantime, especially short-term cooling of a degree or so following major periods of vulcanicity. In the short term it is also likely that the continuing increase of CO₂ in the atmosphere will significantly affect European climate: simulations by models of the atmospheric

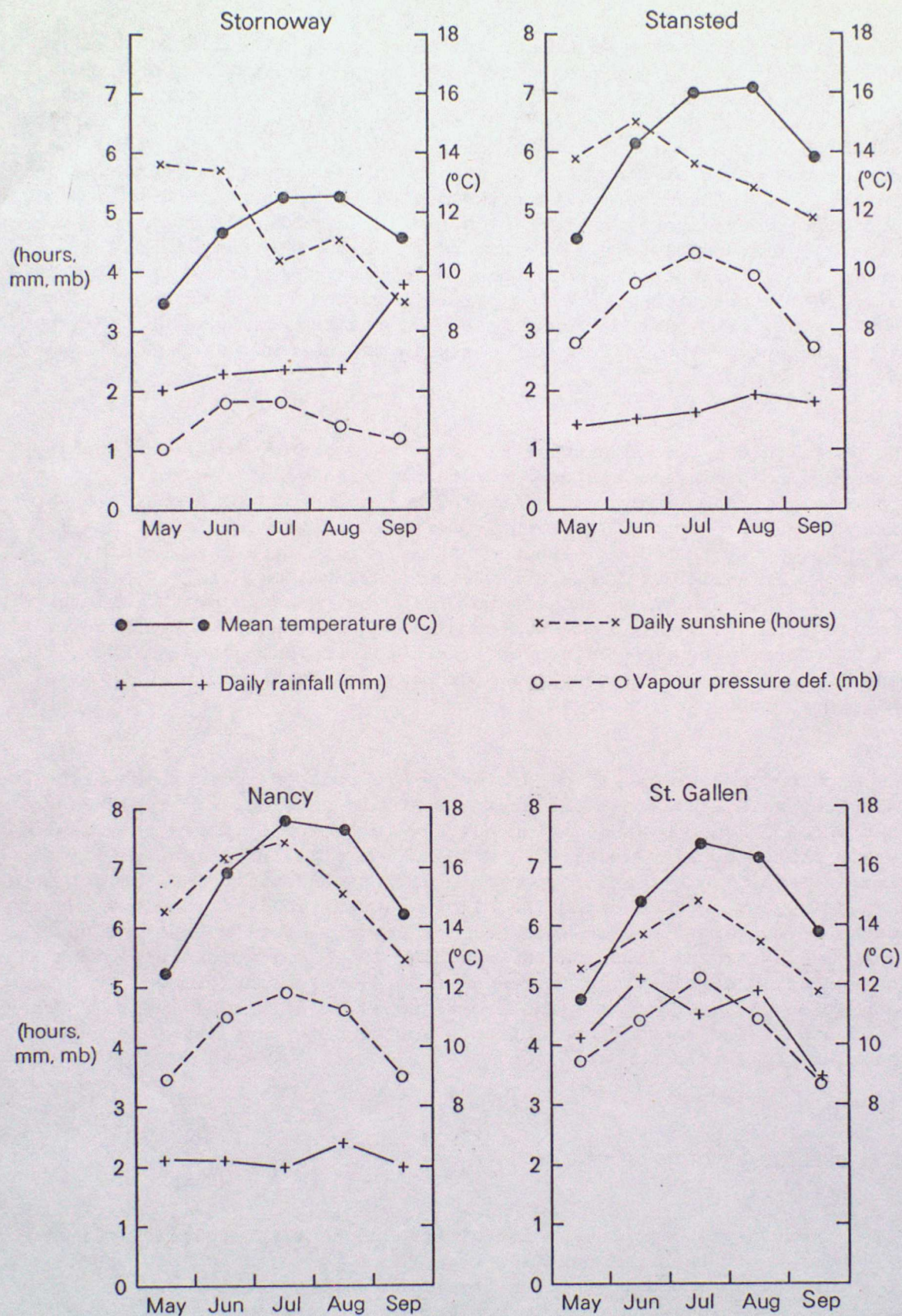
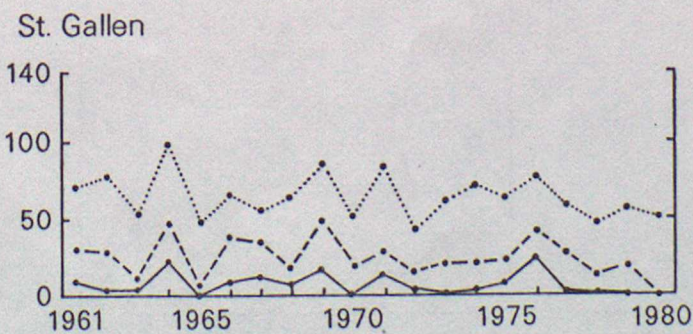
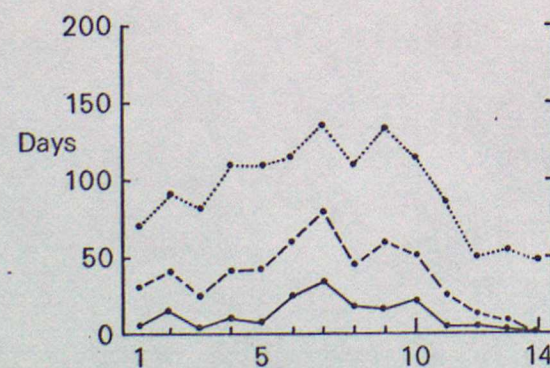
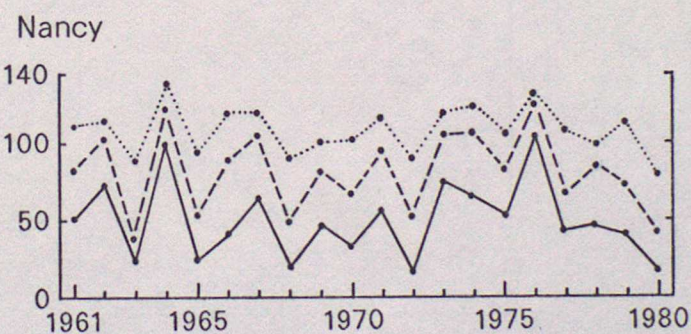
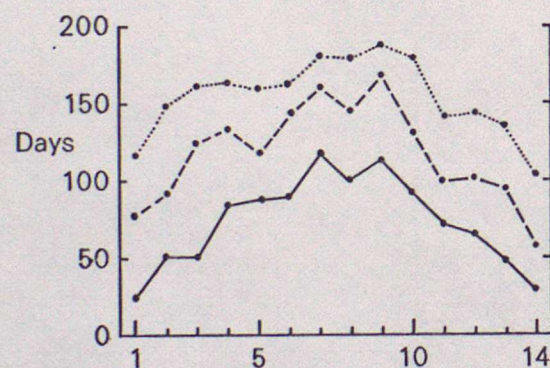
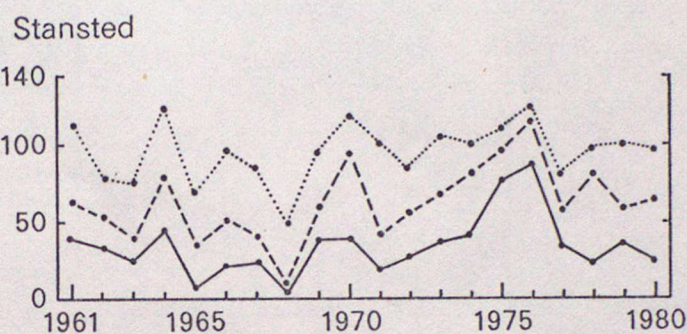
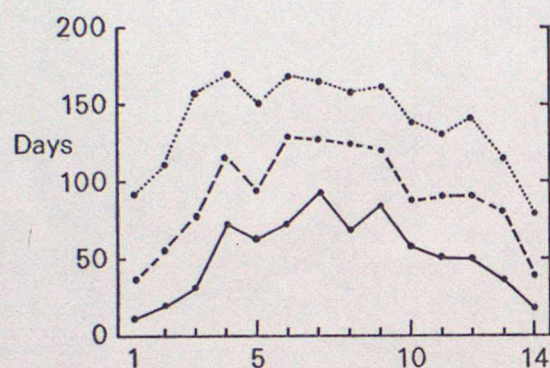
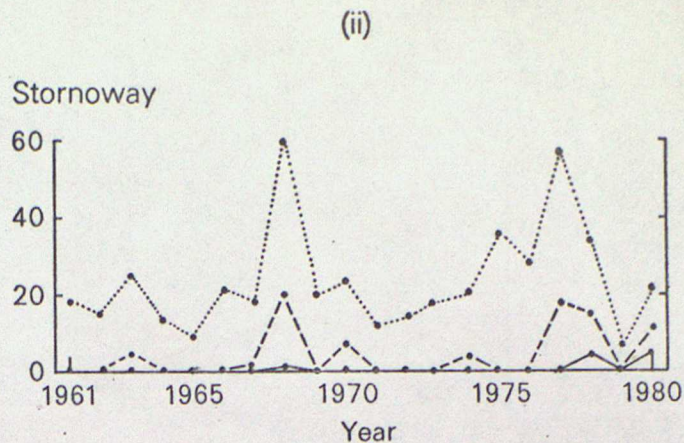
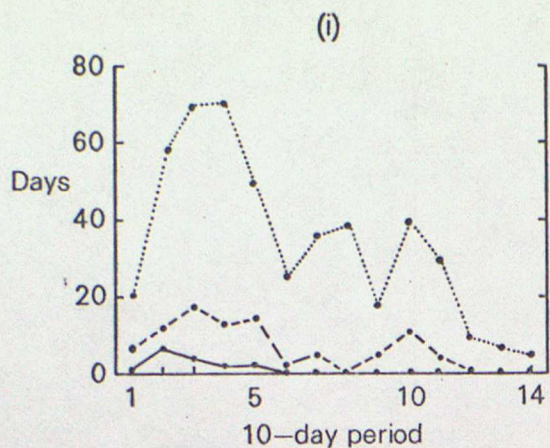
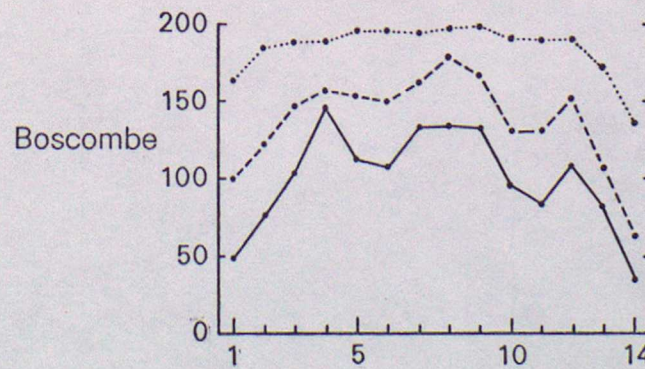
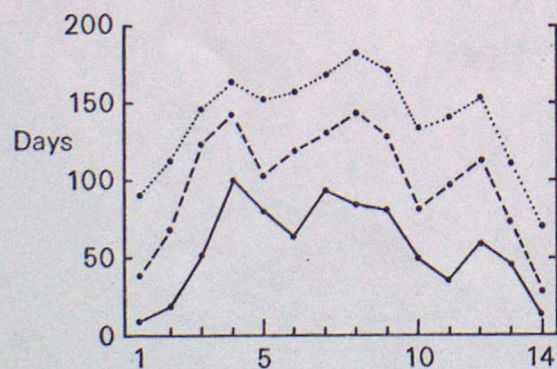
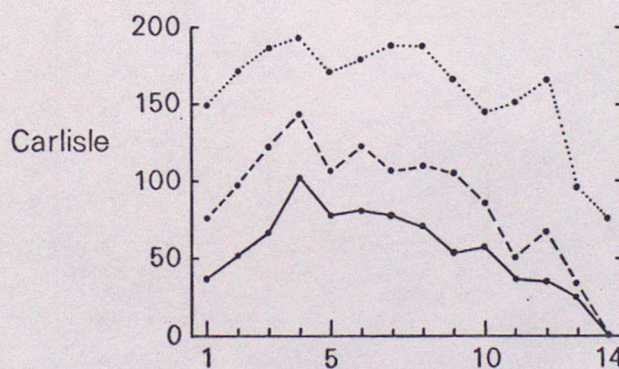
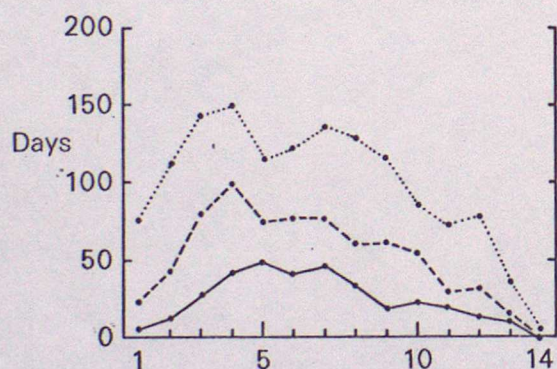
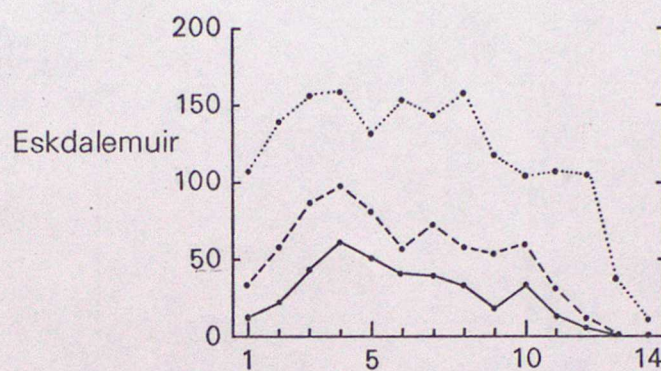
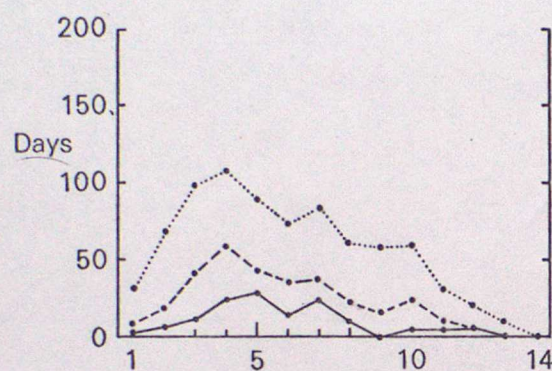
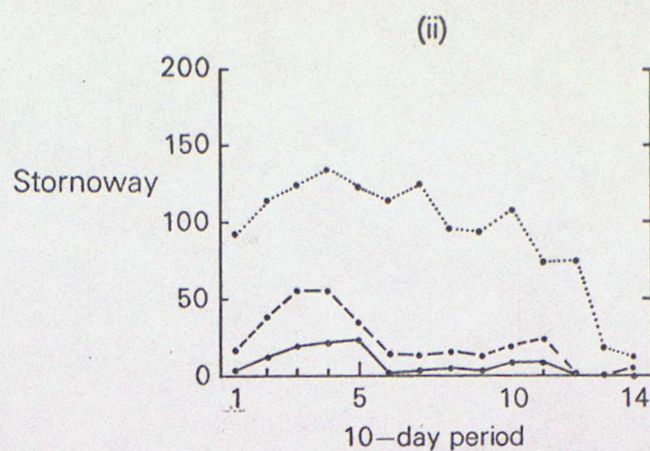
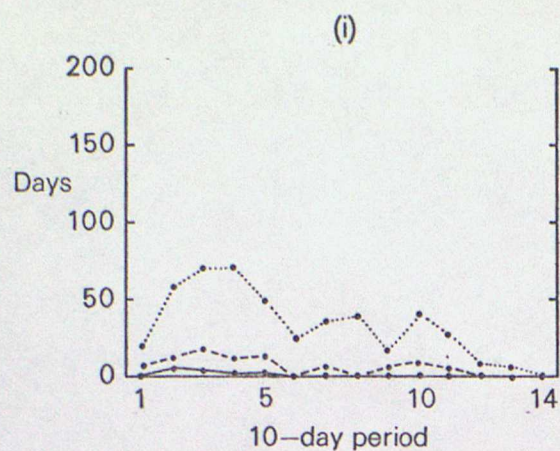


Figure 3 Monthly average values of meteorological variables



- Cuts reaching 25% in ≤ 5 days
- - -•- Cuts reaching 25% in ≤ 10 days
-•..... Cuts reaching 40% in ≤ 10 days.

Figure 4 Number of cuts drying to specified moisture contents
 (i) Number in each 10-day cutting period (all years)
 (ii) Number in each year



- Cuts reaching 25% in ≤ 5 days
- - - Cuts reaching 25% in ≤ 10 days
- Cuts reaching 40% in ≤ 10 days

Figure 5 Number of cuts drying to specified moisture content in each 10-day cutting period (all years) (i) Unconditioned swath (ii) Conditioned swath

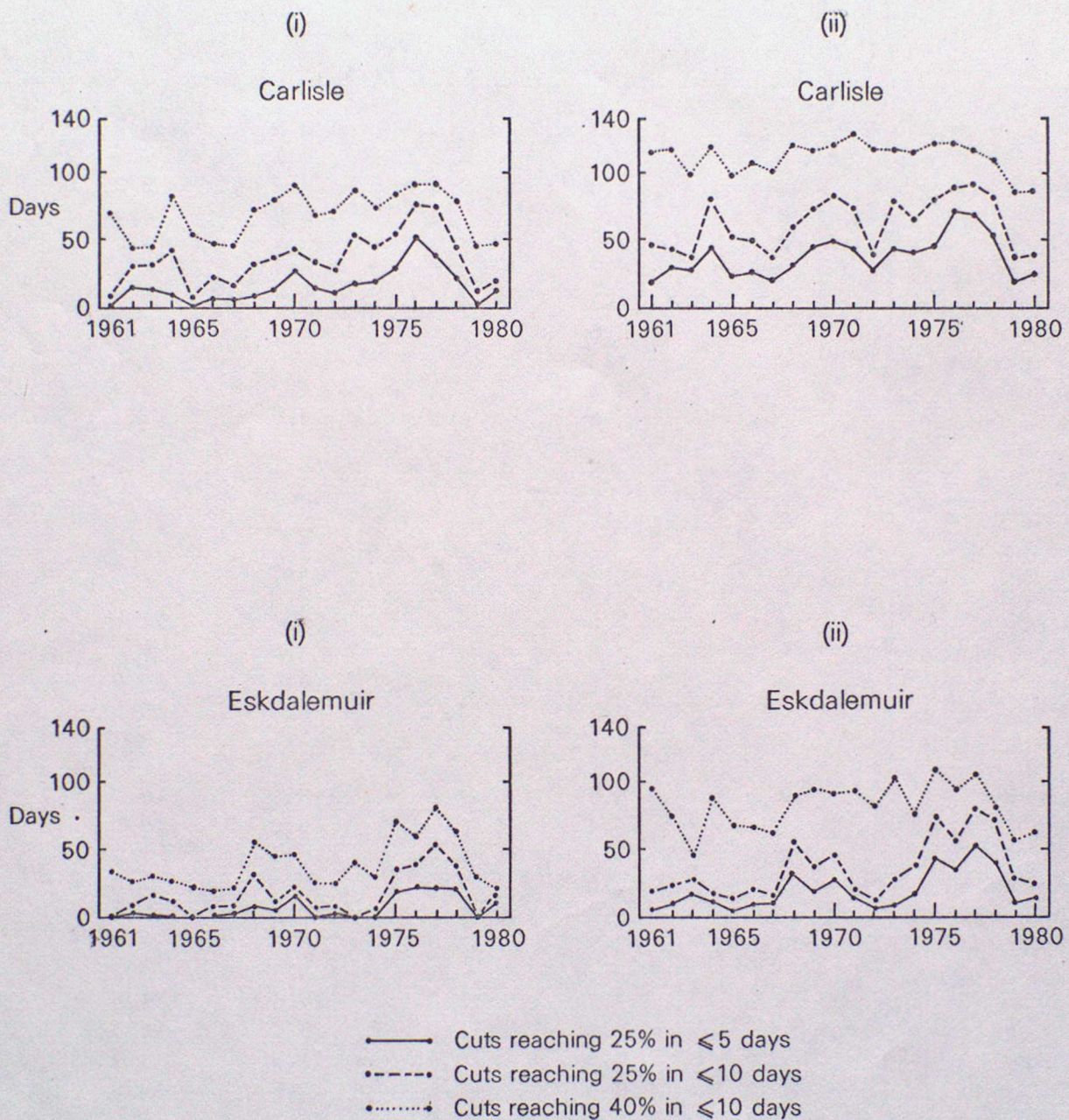


Figure 6 Annual variations in number of cuts drying at Carlisle and Eskdalemuir
(i) Unconditioned swath: (ii) Conditioned swath

Table 3 Average rainfall on the drying swath

Station	Rainfall totals in mm				
	(a)	(b)	(c)	(d)	(e)
Stornoway	0.0	0.3	3.1	0.3	3.7
Dyce	0.4	2.5	5.2	4.1	7.3
Eskdalemuir	0.2	2.3	5.2	3.9	7.2
Carlisle	0.3	3.1	5.8	5.7	8.8
Aldergrove	0.2	2.2	4.2	3.8	6.0
Finningley	0.4	2.7	4.1	6.1	6.8
Shawbury	0.2	2.3	5.3	4.7	8.9
Aberporth	0.1	2.0	4.1	3.3	6.4
Stansted	0.3	1.9	3.7	4.0	7.1
Boscombe	0.3	2.0	4.1	4.3	9.3
Mountbatten	0.2	1.9	6.1	3.7	13.1
De Bilt	0.4	3.3	5.4	7.4	9.4
Eelde	0.4	2.9	4.8	5.7	8.5
Lille	0.4	3.3	5.6	7.2	11.5
Caen	0.4	2.4	4.0	5.3	9.4
Nancy	0.6	3.2	5.3	7.4	11.9
Rostrenan	0.3	2.2	4.1	4.5	8.4
Orleans	0.6	2.9	3.9	8.8	10.9
Cognac	0.5	2.7	3.9	9.8	14.6
Cl.-Ferr.	0.9	4.5	5.5	13.2	18.3
Bremen	0.9	4.7	6.5	10.0	10.7
Hannover	0.9	4.4	6.0	9.0	9.8
Trier	0.9	4.6	6.4	10.1	9.1
Mannheim	1.0	5.0	7.0	12.3	12.6
Nurnberg	0.9	4.7	6.5	10.7	13.2
Munchen	1.6	9.5	12.5	16.5	17.6
Zurich	1.5	9.7	11.8	17.5	15.4
St Gallen	0.4	7.8	13.8	11.0	17.7
Bern	0.8	7.9	10.0	14.3	13.3
Char	1.3	6.6	9.5	13.6	16.7
Geneva	1.1	5.6	7.4	13.6	14.5
Bever	0.5	3.1	7.0	3.2	8.8

(Cuts drying to (a) 25% in ≤ 5 days (b) 25% in ≤ 10 days (c) 40% in ≤ 10 days (d) 25% in 5-10 days (e) 25-40% in ≤ 10 days).

general circulation suggest that this will cause temperature increases over Europe of 2 deg C or more by the time CO₂ concentrations reach double their present values (within the next 50-100 years). However arguments have also been put forward which support much smaller temperature increases. Whichever turn out to be true, a change of temperature of 1 deg C (without changes in the other elements) will produce, according to the haydrying model, only a small increase in the number of cuts drying quickly to storage moisture content in the more adverse climates, for example by 2 or 3 cuts at Stornoway and Eskdalemuir, and 10 cuts at Carlisle. However, doubling CO₂ is likely to increase grass yields by one third, and double water use efficiency of the growing crop (Thompson, 1984), and this has important implications for haymaking: for example, areas which are at present rather too dry for reliable grass production in summer (such as much of France) would then be able to produce a larger crop which field drying would convert to hay of high quality. However, those areas more marginal for haymaking might become even more unfavourable because the lower transpiration (in the absence of a CO₂-induced temperature change) would lead to smaller soil moisture deficits, which would retard haydrying.

6. CONCLUSIONS

The development of a micrometeorologically-based model of swath drying for this study has allowed an objective comparison of the effects of weather on field drying of hay at different sites. It has been possible to show, for example, how the adverse effects of relatively high rainfall at a particular place can be compensated by increases in sunshine or vapour pressure deficit.

A wide range of climates has been considered in the investigation, with a correspondingly wide range of dates at which grass managed in an identical way at all sites would reach a "standard" maturity judged suitable for haydrying, as well as a range of grassland management practices. However, the scheme of analysis used, in which cuts of grass at a fixed moisture content are assumed possible on every day of a prolonged cutting season, is unrealistic in a number of ways but leads to an objective assessment of the potential of the local climate for haydrying, and thus to a feasible intercomparison of prospects for haydrying at different sites.

The analysis, which has concentrated more especially on the making of "good" hay (reaching 25% moisture content within 5 days of cutting) has shown that such drying is associated with only small rainfall amounts on the swath (<1 mm). As expected, a larger number of conditioned swaths are calculated to become good hay, but with some increase in the average rainfall total on the drying swath. Extending the drying period to 10 days roughly doubles the number of cuts which reach 25% moisture content at sites with only moderate prospects for haydrying. However, rainfall

totals on the additional drying swaths are considerably larger, ranging from around 4 mm in the Northwest to 10 mm or more at most southeastern sites, with consequential loss of quality and dry matter.

Hay is sometimes baled when its moisture content falls below 40%, followed by a further period of field curing: consideration of this last has been specifically excluded from the investigation. The results show that a substantial number of cuts which fail to reach 25% moisture within 10 days will dry to the potentially baleable state, but average rainfall amounts on such swaths are high.

A large inter-annual variability has been demonstrated at the sites considered, including those offering very good prospects for haydrying on average. In the northwest of the United Kingdom where the chance of making good hay is poor on average, there are clearly years when it will be impossible to make hay of other than low quality.

The seasonal pattern of field-drying potential is shown to change in moving from the maritime climate of the northwest of the United Kingdom to the continental and sub-alpine climates of sites in mainland Europe. Best haydrying prospects in the maritime climate are around the beginning of June, unfortunately when grass is usually rather immature for a hay cut. This contrasts with most other sites where better weather for haydrying more closely equates with the appropriate grass maturity.

Possible consequences of climate change, from various causes, have been considered briefly. It is shown that small changes of temperature (+ 1 deg C) would enhance only slightly the haydrying prospects at the most unfavourable sites. Effects of increase of atmospheric CO₂ on crop yield and water use efficiency, will, even in the absence of any resulting changes in values of the meteorological variables, produce both beneficial and adverse effects on haydrying, depending on location of site.

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(Keywords: Hay; Field-drying; Climatology)

Any comments or suggestions on this paper should be referred to the author.

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